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In-Service Solvent Cleaning of Electric Motors

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In-Service Solvent Cleaning of Electric Motors

D. L. STODDARD and W. R. WELLS

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A method is described for the in-service solvent cleaning of dirt fouled electric motors employing a stream of solvent directed into the end bell opening of the operating motors. Solvent vapors are directed to the outside atmosphere by appropriate ventilation arrangements and dirty solvent that drains out of the motors is collected in a container and with rags. The results are substantial cleaning of the motors, significant lowering of motor operating temperatures and extended motor life without exposing unprotected employees to dangerous concentrations of solvent vapors. Methyl chloroform is less damaging to motor insulation and the fumes are more easily controlled than the other solvents tested.

IN-SERVICE cleaning of large electric motors has been accomplished at the Oak Ridge Gaseous Diffusion Plant (O.R.G.D.P.) using carbon tetrachloride[1] and inhibited methyl chloroform as cleaning agents. This cleaning has been done without exposure of employees to hazardous solvent vapor levels. Carbon tetrachloride was the first solvent used because it had long been accepted as a satisfactory degreasing agent for electrical equipment.[2] Methyl chloroform was subsequently used after tests proved it to be more desirable than carbon tetrachloride.[1,3,4] This cleaning costs approximately two man-hours and $7.35 worth of materials per motor.

This paper describes (1) how the motors were cleaned with carbon tetrachloride; (2) the problems encountered in using carbon tetrachloride; (3) the tests in the search for a substitute for carbon tetrachloride and (4) a summary of our present practice using inhibited methyl chloroform.

The Problem

Dirt fouling of the O.R.G.D.P. electric motors caused them to overheat by interfering with the passage of cooling air between the field coil windings. Even though these motors had been operated in a locale of apparent good housekeeping they accumulated a little dust from each volume of air that passed through them. When oil fumes and mists were present due to leakage from the motor bearings and the recirculating oil system, the deposition rate was greater. As the accumulation of dust particles grew it reduced the efficiency of the subsequent cooling air until the accumulation was great enough to cause a rise in the motor temperatures. With the increase in operating temperature there was an increase in the rate of insulation depreciation and a corresponding decrease in the expected "use life" of the motor.[5] A solution to this problem of increased motor temperature had been accomplished in the past by replacing the motor with a precleaned motor.

For economic and operational reasons, motors are operated continuously; it was therefore more desirable to remove the excess oil, grease, and dirt from them with a minimum of interruption. The new in-service cleaning procedure that is to be described was developed for these reasons.

Initially to demonstrate use of carbon tetrachloride in-place cleaning, a group of motors were partially disassembled for internal examination, reassembled, suspended in a ventilated tank, and operated at reduced voltage while streams of carbon tetrachloride were directed at varying flow rates into the end openings. The solvent wet motors were allowed to dry, disassembled and re-examined. The results of these cleaning tests were favorable. The interiors of some of the cleaned motors were comparable to those precleaned in the shop; particularly those into which the solvent had been squirted at a rate of ap-

This paper is based on work performed at the Oak Ridge Gaseous Diffusion Plant operated by Union Carbide Corporation for the U. S. Atomic Energy Commission. Presented at the Twenty-second Annual Meeting of the American Industrial Hygiene Association, Detroit, Michigan, April, 1961.

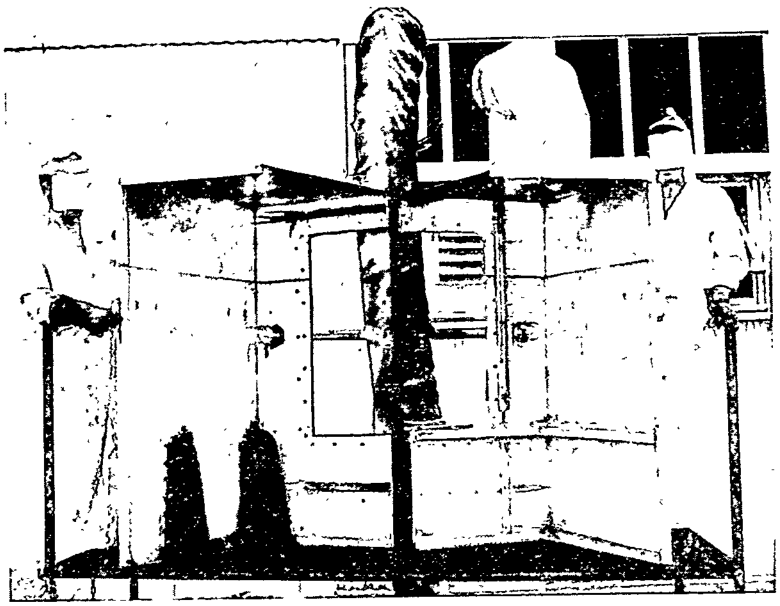

FIGURE 1. Photograph of the adjustable hood used during in-service cleaning of motors.

proximately five gallons per minute. Motors cleaned in this manner would again operate in their designed temperature range.

Cleaning with Carbon Tetrachloride

The initial in-service cleaning of operating electric motors was done in June 1951[1] using carbon tetrachloride as the solvent. A prototype hood of canvas on a pipe frame was placed over the motor to be cleaned. A flexible exhaust duct led to an air mover which exhausted into a roof ventilator. This combination was later replaced by an adjustable aluminum exhaust hood shown in Figure 1 and a blower. Even with the hood, it was difficult to control the vapors. Personnel protective devices, work area isolation by barricade and constant monitoring was necessary to prevent unprotected employees from entering a zone of heavy concentrations of carbon tetrachloride vapors. In a typical situation, the airborne concentration of the solvent would be in the range of 100-150 ppm for most of the period of cleaning and peak concentrations would be of the order of 240 ppm.

Employee Control

The problem of employee control required that the medical records of the equipment cleaning personnel be carefully examined by the plant medical staff to determine if any condition, past or present, existed which was not compatible with potential exposure to chronic low level or possible acute high level concentrations of the solvent. Only those equipment cleaners passed by a physician were assigned this type job. All employees wore special safety equipment while cleaning operations were in progress and for a period after its completion until the monitored vapor level in the vicinity of the job and in the surrounding areas had dropped below the threshold limit value.

The safety equipment, worn by the equipment cleaners, consisted of impervious hats and suits made of neoprene-latex impregnated cotton fabric, high-top shoes, neoprene gloves and gas masks with canisters for organic vapors. Supervisors, observers and other visitors were required to wear absorbent cartridge respirators while inside the controlled area.

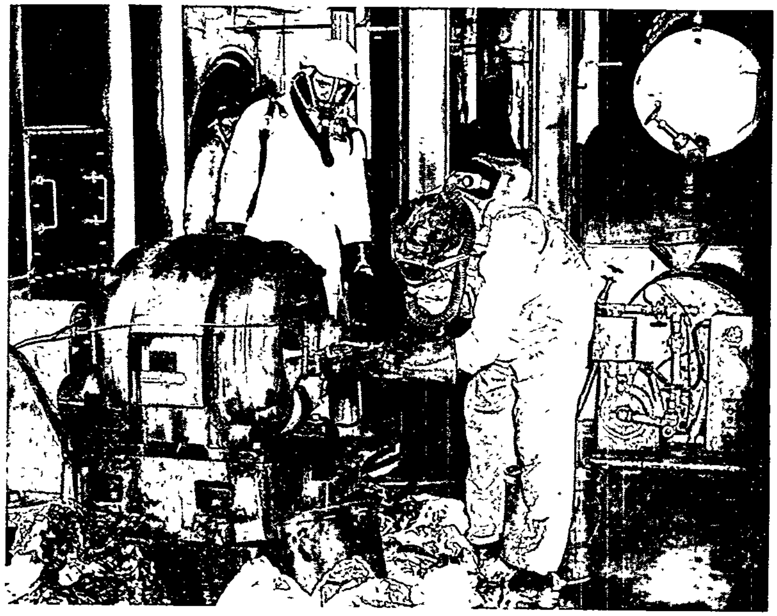

FIGURE 2. Crew cleaning a motor; catch-pan and rags are in place to retain solvent.

Evaluation of Solvents

We now undertook a search for a more desirable solvent, since the toxicologic hazard of the high concentrations of carbon tetrachloride fumes generated was a major industrial hygiene problem. This problem could not be economically relieved by ventilation alone. A study of the ventilation system revealed that the air flow was multidirectional with some still areas. Diverting the air in one direction and adding diffusers helped ease but did not solve the problem of fume control. A substitute solvent therefore was sought to meet the following requirements: it must (1) achieve the same cleanliness level; (2) maintain good dielectric properties; (3) not damage insulating materials; (4) have approximately the same drying rate; (5) be nonflammable and (6) be less toxic by a rather large factor.[6,7]

Three solvents evaluated were 1,1,1-trichloroethane, inhibited 1,1,1-trichloroethane, and trichlorotrifluoroethane using carbon tetrachloride as a comparison standard.

Sections of typical motor field coil windings were degreased with these four solvents and subjected to a series of tests for moisture absorption, solvent action on the insulation, and possible shift in the dielectric properties. Inhibited 1,1,1-trichloroethane and trichlorotrifluoroethane were superior in all tests. Corrosion rates of these solvents were determined on samples of the metals of construction of the motors and again these two solvents gave superior performance.

Since the cost of trichlorotrifluoroethane in the amounts necessary to effectively clean motors was so great as to be prohibitive, the balance of the evaluation effort was concentrated on the inhibited 1,1,1-trichloroethane, hereinafter referred to as methyl chloroform.

Torkelson *et al.*[7] stated that if large amounts of heat, such as an open flame or a red hot wire, are applied the methyl chloroform vapors could burn. In anticipation of a probable high intensity arc developing in a motor while the solvent was in it, a laboratory test was designed to reproduce the worst possible situation. Variable concentrations of methyl chloroform vapors in air were passed over a high intensity arc in a closed, glass system. In the range of 1.1% to 83.0% by weight of methyl chloroform in air, the solvent burned in the immediate zone of the

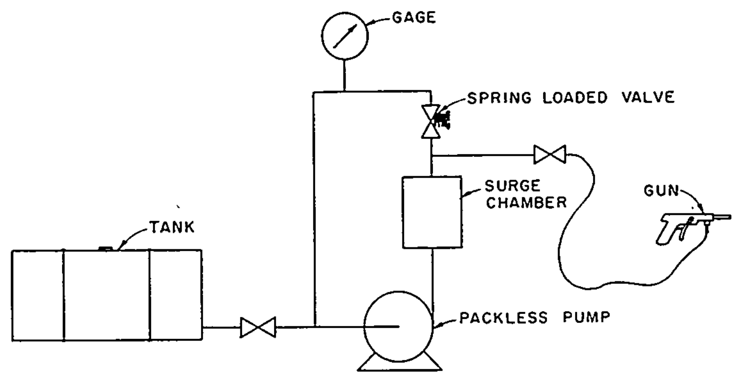

FIGURE 3. Schematic diagram of the solvent pressure system.

electric arc. Combustion ceased each time the arc was interrupted. When a hydrogen-oxygen torch flame was directed into an open dish of methyl chloroform the solvent burned readily with a yellow smokey flame. The combustion ceased when the flame was removed.

Summary of Present Practice

An acceptable substitute for carbon tetrachloride as the cleaning solvent has been established and a major change has been made in the ventilation system of the process buildings. These changes have made it possible to use one large portable blower and direct all waste solvent vapors to the most convenient roof ventilator without the flexible duct used previously.

The use of methyl chloroform as the solvent has simplified the employee control phase of the program. The impervious clothing is no longer needed. It has been replaced by launderable coveralls and caps; this less cumbersome equipment allows more freedom of movement. The masks, neoprene gloves and shoes are still required. Higher atmospheric concentrations of the solvent are tolerated at a lower hazard level. Monitoring for solvent vapors has been reduced to specific areas.

The simplified procedure is performed without a hood but under similar area controls. The ventilation is adjusted. A catch pan is placed under the motor to direct waste solvent into a bucket. A ring of rags is applied to the base of the motor mount to absorb solvent escaping down the sides. The operation is shown in Figure 2. The solvent is directed from the gun into each end bell opening at a rate of 7.5 gallons per minute for a number of seconds, depending on the size of the motor, up to a maximum of 10 seconds per opening. A small timer was mounted on the spray-head to enable the operator to judge and control the time the spray was on.

The rags around the motor mount are used to clean up the dirty solvent that escapes the catch pan and bucket. These rags are then placed in large, covered cans for reclaiming.

Approximately half of the solvent used on each motor is recovered and allowed to settle in drums. This solvent, when separated from the sediment by decanting and mixed with not less than an equal quantity of fresh methyl chloroform, may be used for subsequent motor cleaning.

The Solvent System

The gun chosen for applying the cleaning solvent was an external-mix, paint spray-gun equipped with the inner tip of an underbody coating spray-head to which a tapered extension had been attached. The extension delivered a stream of solvent with very little turbulence to cause spatter. The fluid inlet of the gun was attached to the solvent pressure system by a reinforced neoprene hose.

The solvent was supplied to the gun from a tank mounted on a low cart. Fluid pressure was developed by a packless electric pump which discharged into a recycle loop (Figure 3). From one branch of the loop the solvent flowed to the solvent gun. This ar-

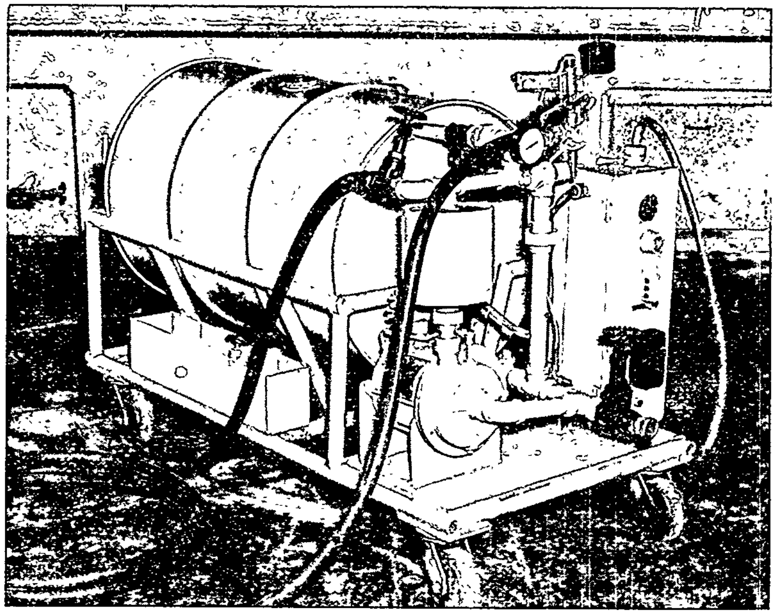

FIGURE 4. Mobile solvent pressure system used for in-service cleaning of electric motors.

rangement allowed the pump to remain primed at all times and maintain the solvent in motion at a working pressure. Additional valves on the pump intake and exhaust lines allowed the tank to be refilled from solvent supply drums when gravity feed was not possible. The mobile unit is shown in Figure 4.

Operational Experience

The method for cleaning electric motors while in service, using carbon tetrachloride as the cleaning solvent, was used on several thousand motors ranging up to 150 horsepower. As many as 35 motors were cleaned by a crew of five men in a single day.

The simplified system, with methyl chloroform, has been used to clean approximately 800 motors ranging up to 200 horsepower. Three motors reacted to the cleaning procedure but did not stop running. Examination of these motors indicated that a short circuit had existed in two of them for a very short period, but they did not catch fire. It was concluded that the solvent interrupted the short circuit and either prevented or extinguished any resulting fire. What occurred in the third motor was never definitely determined.

Conclusions

Safe handling of large amounts of hazardous cleaning solvents and the resultant vapors made possible the development of a method for cleaning electric motors while in service under normal load, without interrupting their operation, thereby extending their expected "use life."

The cleaning was done successfully with several different solvents. Motors as large as 200 horsepower were cleaned with the expenditure of approximately two manhours of labor and $7.35 for materials per motor.

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IN-SERVICE SOLVENT CLEANING OF ELECTRIC MOTORS *

APPROVAL FOR RELEASE

Approval for the release of this document is authorized by the U. S. Atomic Energy Commission under an entry dated April 5, 1961 on an exact copy.

W. L. Harwell for

Date April 7 1961.

*This document is based on work performed at the Oak Ridge Gaseous Diffusion Plant operated by Union Carbide Corporation for the U. S. Atomic Energy Commission.

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Union Carbide Nuclear Company
Oak Ridge, Tennessee

IN-SERVICE SOLVENT CLEANING OF ELECTRIC MOTORS

D. L. Stoddard, Industrial Relations Division
and W. R. Wells, Production Division
Oak Ridge Gaseous Diffusion Plant
Union Carbide Nuclear Company
Oak Ridge, Tennessee

In-service cleaning of large electric motors has been accomplished at the Oak Ridge Gaseous Diffusion Plant using carbon tetrachloride[1] and methyl chloroform as cleaning agents. This cleaning has been done without exposure of employees to hazardous solvent vapor levels.

Carbon tetrachloride was the first solvent used because it had long been accepted as a satisfactory degreasing agent for electrical equipment[2]. Methyl chloroform was subsequently used after tests proved it to be more desirable than carbon tetrachloride[1,3,4].

This cleaning costs approximately 2 manhours and $7.35 worth of materials per motor.

This paper describes (1) how the motors were cleaned with carbon tetrachloride; (2) the problems encountered in using carbon tetrachloride; (3) the tests in the search for a substitute for carbon tetrachloride and (4) a summary of our present practice using methyl chloroform.

THE PROBLEM

Dirt fouling of the O.R.G.D.P. electric motors caused them to overheat by interfering with the passage of cooling air between the field coil windings. Even though these motors had been operated in a locale of apparent good housekeeping they accumulated a little dust from each volume of air that passed through them. When oil fumes and mists were present due to leakage from the motor bearings and the recirculating oil system, the deposition rate was greater. As the collection of dust particles grew it reduced the efficiency of the subsequent cooling air until the accumulation was great enough to cause a rise in the motor temperatures. With the increase in operating temperature there was an increase in the rate of insulation depreciation and a corresponding decrease in the expected "use life" of the motor[5]. A solution to this problem of increased rotor temperature had been accomplished in the past by replacing the motor with a precleaned motor.

For economic and operational reasons, motors are operated continuously; it was therefore more desirable to remove the excess oil, grease, and dirt from them with a minimum of interruption. The new in-service cleaning procedure that is to be described was developed for these reasons.

Initially to demonstrate use of carbon tetrachloride in-place cleaning, a group of motors were partially disassembled (Figure 1) for internal

(Figure 1)

examination, reassembled, suspended in a ventilated tank, and operated at reduced voltage while streams of carbon tetrachloride were directed at varying rates into the end openings. The solvent wet motors were allowed to dry, disassembled and re-examined (Figure 2). The results of these

(Figure 2)

cleaning tests were favorable. The interiors of some of the cleaned motors were comparable to those precleaned in the shop; particularly those into which the solvent had been squirted at a rate of approximately 5 gallons per minute. Motors cleaned in this manner would again operate in their designed temperature range.

CLEANING MOTORS WITH CARBON TETRACHLORIDE

The initial in-service cleaning of operating electric motors was done in June 1951[1] using carbon tetrachloride as the solvent. A prototype hood of canvas on a pipe frame was placed over the motor to be cleaned. A

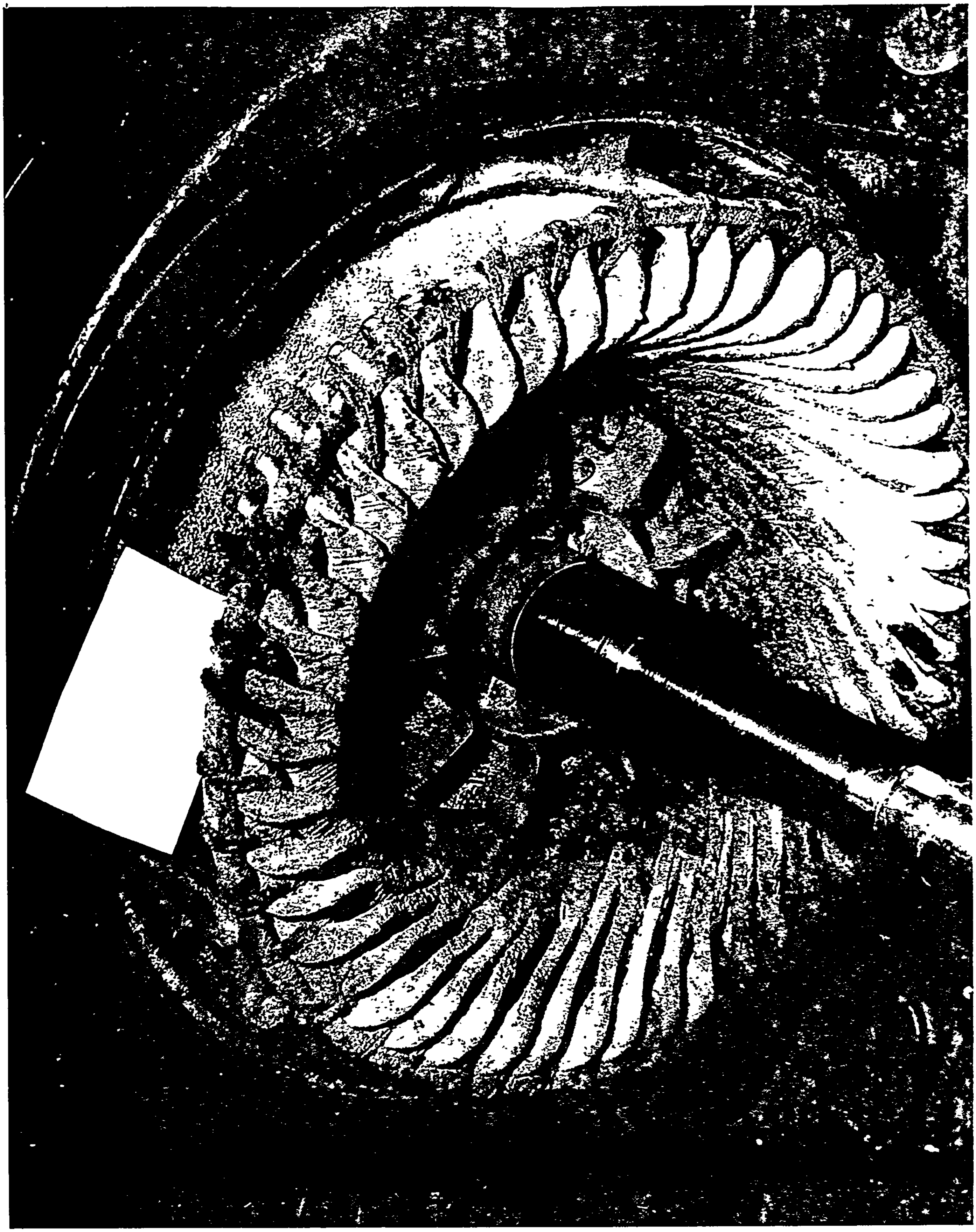


Figure 1. Dismantled Motor, Dirty.

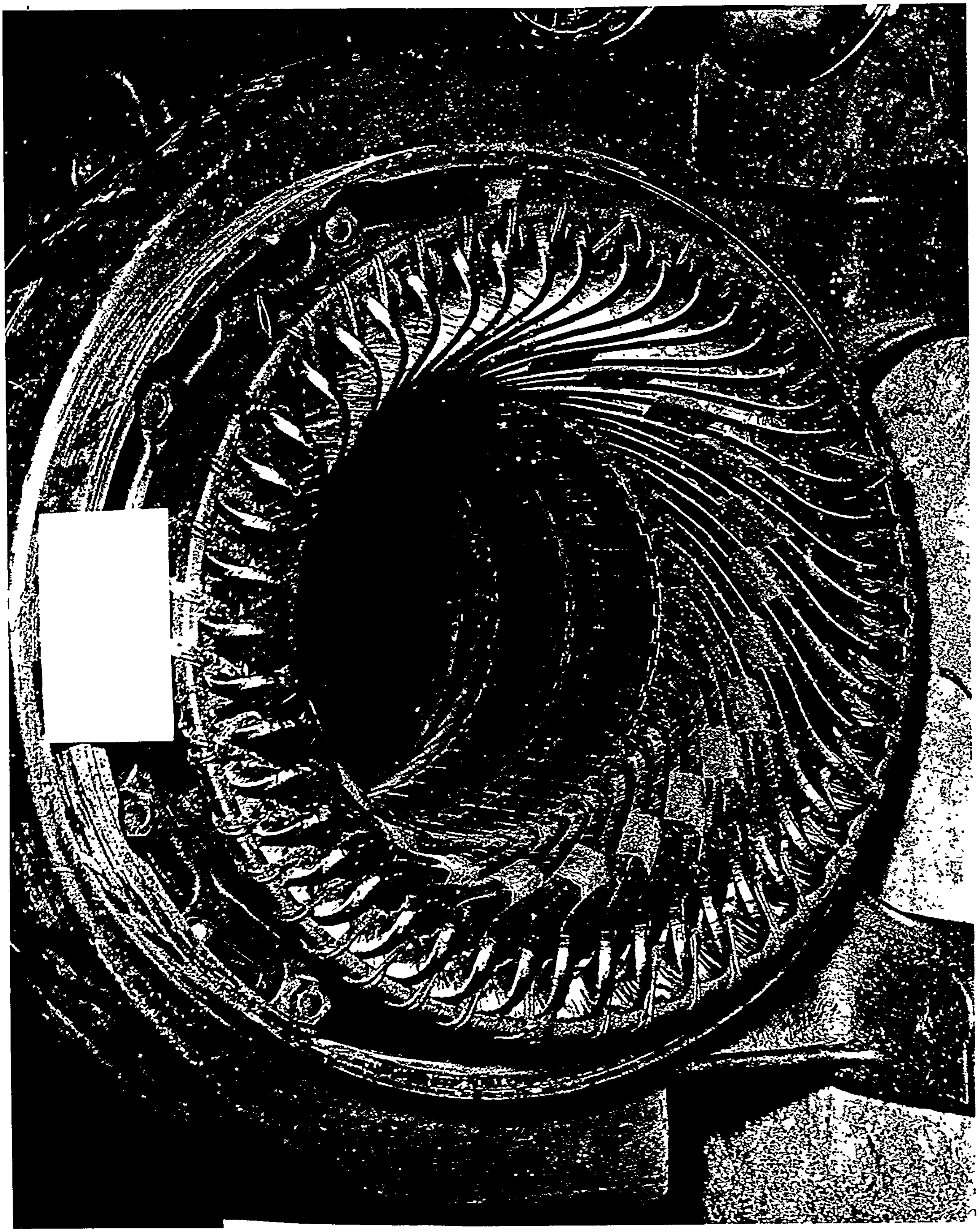


Figure 2. Dismantled Motor, Cleaned.

flexible exhaust duct led to an air mover which exhausted into a roof ventilator. This combination was later replaced by an adjustable aluminum exhaust hood shown in Figure 3 and a blower. Even with the hood, it was difficult to control the vapors. Personnel protective devices, work area isolation by barricade and constant monitoring was necessary to prevent unprotected employees from entering a zone of heavy concentrations of carbon tetrachloride vapors. A typical recording of the airborne concentration of the solvent is shown in Figure 4.

(Figure 3)

(Figure 4)

EMPLOYEE CONTROL

The problem of employee control required that the medical records of the equipment cleaning personnel be carefully examined by the plant medical staff to determine if any condition, past or present, existed which was not compatible with potential exposure to chronic low level or possible acute high level concentrations of the solvent. Only those equipment cleaners passed by a physician were assigned this type job. All employees wore special safety equipment while cleaning operations were in progress and for a period after its completion until the monitored vapor level in the vicinity of the job and in the surrounding areas had dropped below the threshold limit value.

The safety equipment, worn by the equipment cleaners, consisted of impervious hats and suits made of neoprene-latex impregnated cotton fabric, high top shoes, neoprene gloves and gas masks with canisters for organic vapors. Supervisors, observers and other visitors were required to wear absorbent cartridge respirators while inside the controlled area.

SEARCH FOR A MORE DESIRABLE SOLVENT

We now undertook a search for a more desirable solvent, since the

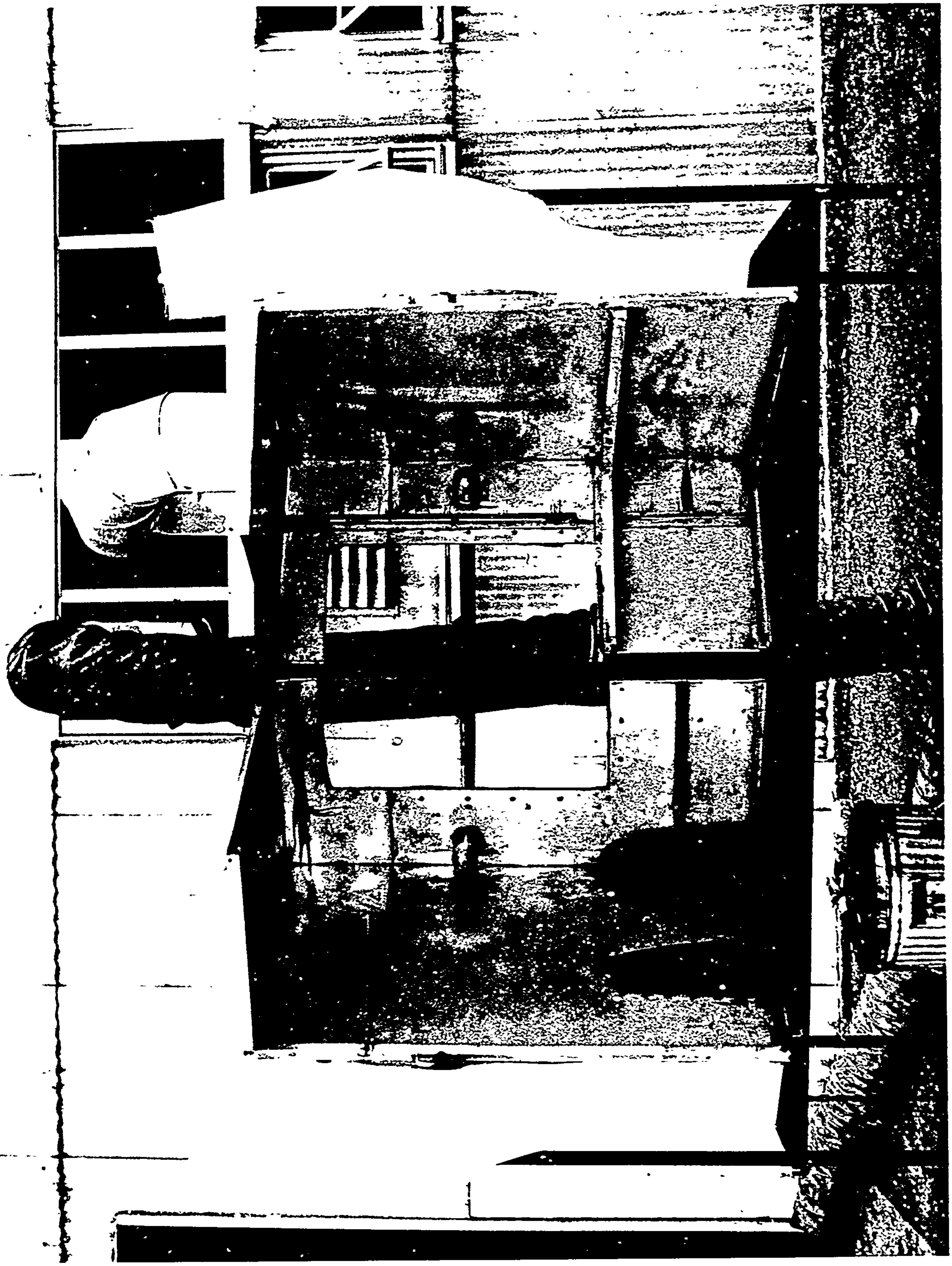
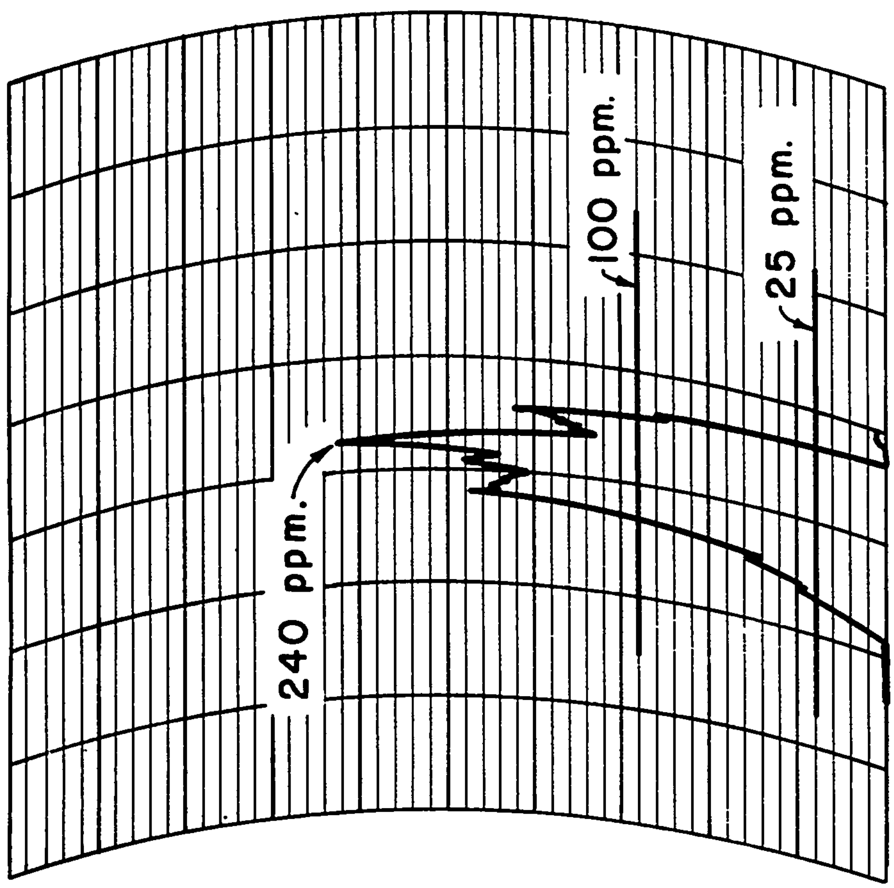


Figure 3. Adjustable Hood.



TYPICAL RECORDING OF CARBON TETRACHLORIDE CONCENTRATION IN AIR

Figure 4. Typical Recording of Carbon Tetrachloride Concentrations in Air.

highly toxic nature of the large concentrations of carbon tetrachloride fumes generated was a major industrial hygiene problem. This problem could not be economically relieved by ventilation alone. A study of the ventilation system revealed that the air flow was multidirectional with some still areas. Diverting the air in one direction and adding diffusers helped ease the problem of fume control. A substitute therefore was sought meeting the following requirements, as shown in Table I, it must (1)
(Table I)
(Figure 5) achieve the same cleanliness level; (2) maintain good dielectric properties; (3) not damage insulating materials; (4) have approximately the same drying rate; (5) be nonflammable and (6) be less toxic by a rather large factor[6,7].

Three solvents evaluated were 1,1,1 trichloroethane, inhibited 1,1,1 trichloroethane, and trichlorotrifluoroethane using carbon tetrachloride as a comparison standard.

Sections of typical motor field coil windings were degreased with these four solvents and subjected to a series of tests for moisture absorption, solvent action on the insulation, and possible shift in the dielectric properties. Inhibited 1,1,1 trichloroethane and trichlorotrifluoroethane were superior in all tests. Corrosion rates of these solvents were determined on samples of the metals of construction of the motors and again these two solvents gave superior performance.

Since the cost of trichlorotrifluoroethane in the amounts necessary to effectively clean motors was prohibitive, the balance of the evaluation effort was concentrated on the inhibited 1,1,1 trichloroethane, hereinafter referred to as methyl chloroform.

Torkelson et al[7] stated that if large amounts of heat, such as an open flame or a red hot wire, are applied the methyl chloroform vapors could

TABLE I

CRITERIA FOR CARBON TETRACHLORIDE SUBSTITUTE

<u>It Must:</u>

1. Achieve the same cleanliness level.
2. Maintain good dielectric properties.
3. Not damage insulating materials.
4. Have approximately the same drying rate.
5. Be nonflammable.
6. Be less toxic by a rather large factor.

Figure 5. Solvent Criteria (Table I).

burn. In anticipation of a probable high intensity arc developing in a motor while the solvent was in it, a laboratory test was designed to reproduce the worst possible situation. Varying concentration of methyl chloroform vapors in air were passed over a high intensity arc in a closed glass system. In the range of 1.1% to 83.0% by weight of methyl chloroform in air, the solvent burned in the immediate zone of the electric arc. Combustion ceased each time the arc was interrupted. When a hydrogen-oxygen torch flame was directed into an open dish of methyl chloroform the solvent burned readily with a yellow smokey flame. The combustion ceased when the flame was removed.

SUMMARY OF PRESENT PRACTICE

An acceptable substitute for carbon tetrachloride as the cleaning solvent has been established and a major change has been made in the ventilation system of the process buildings. These changes have made it possible to use one large portable blower and direct all waste solvent vapors to the most convenient roof ventilator without the flexible duct used previously.

The use of methyl chloroform as the solvent has simplified the employee control phase of the program. The impervious clothing is no longer needed. It has been replaced by launderable coveralls and caps; this less cumbersome equipment allows more freedom of movement. The masks, neoprene gloves and shoes are still required. Higher atmospheric concentrations of the solvent are tolerated at a lower hazard level. Monitoring for solvent vapors has been reduced to specific areas.

The simplified procedure is done without a hood but under similar area controls. The ventilation is adjusted. A catch pan is placed under the motor to direct waste solvent into a bucket. A ring of rags is applied to the base of the motor mount to absorb solvent escaping down the sides (Figure 6). The solvent is directed from the gun into each end bell opening at a rate of 7.5 gallons per minute for a number of seconds, depending on the size of the motor, up to a maximum of 10 seconds per opening (Figure 7).

(Figure 6)

(Figure 7)

The rags around the motor mount are used to clean up the dirty solvent that escapes the catch pan and bucket. These rags are then placed in large, covered cans for reclaiming.

Figure 8 shows the inside of an operating motor before cleaning; Figure 9 the inside of a motor immediately after it had been cleaned.

(Figure 8)

(Figure 9)

Approximately half of the solvent used on each motor is recovered and allowed to settle in drums. This solvent, when separated from the sediment by decanting and mixed with not less than an equal quantity of fresh methyl chloroform, may be used for subsequent motor cleaning.

THE SOLVENT SYSTEM

The gun chosen for applying the cleaning solvent was an external mix paint spray gun equipped with the inner tip of an underbody coating spray head to which a tapered extension had been attached. The extension delivered a stream of solvent with very little turbulence to cause spatter. The fluid inlet of the gun was attached to the solvent pressure system by a reinforced neoprene hose.

The solvent was supplied to the gun from a tank mounted on a low cart. Fluid pressure was developed by a packless electric pump which discharged into a recycle loop (Figure 10). From one branch of the loop the solvent flowed to the solvent gun. This arrangement allowed the pump to remain

(Figure 10)

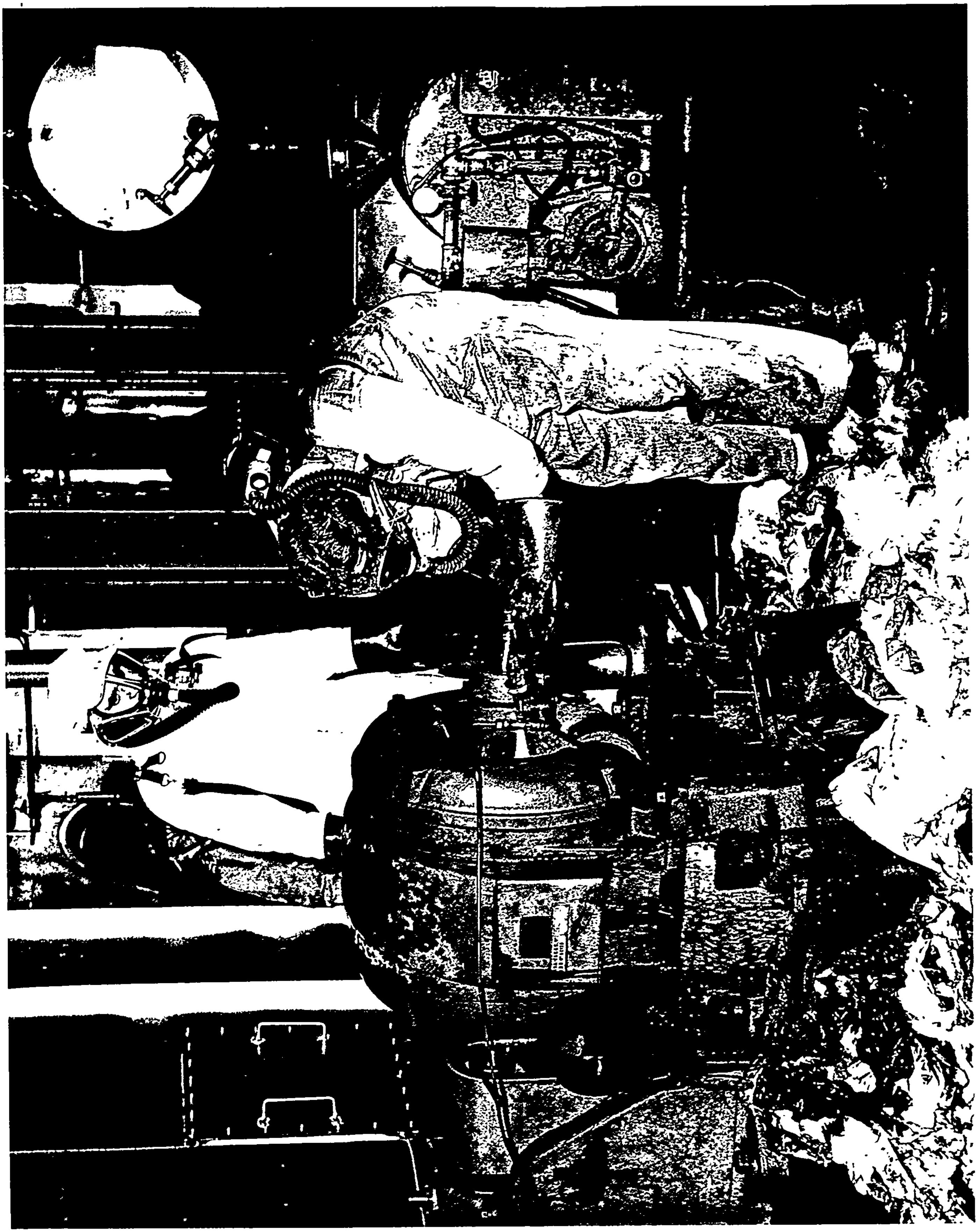


Figure 6. Motor Cleaning in Operation.

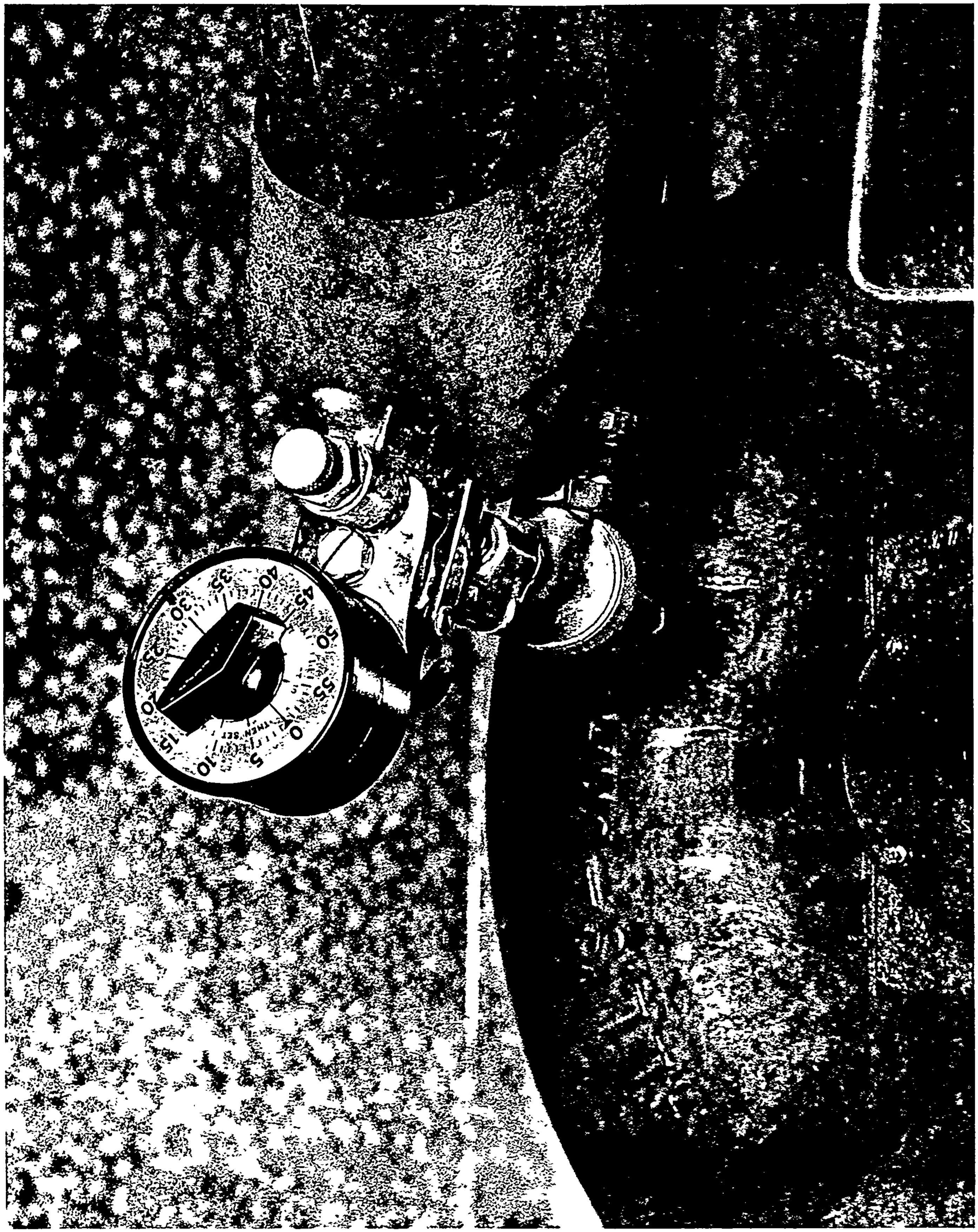


Figure 7. Timer on Gun.

Figure 8. Inside Motor, Dirty.

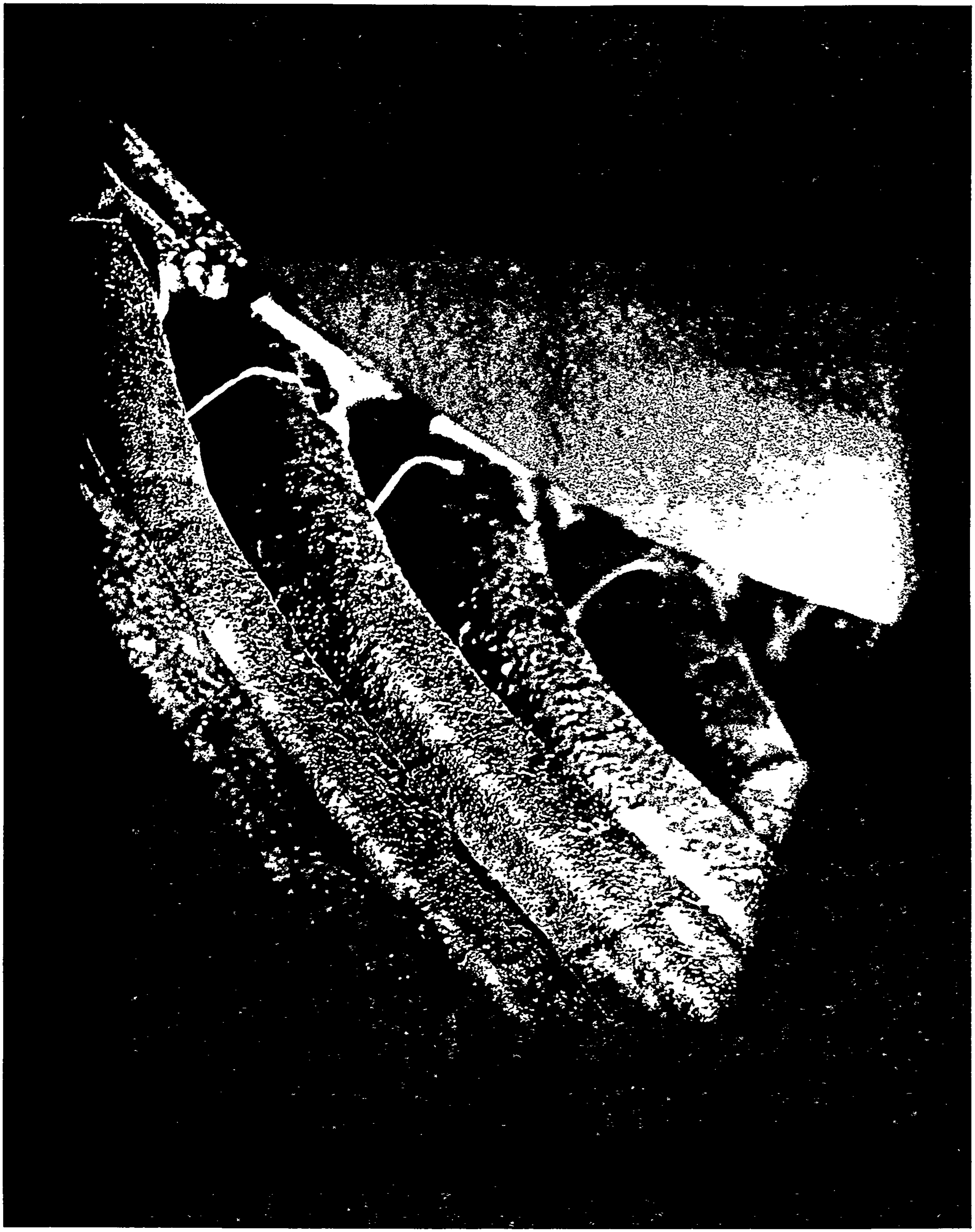


Figure 9. Inside Motor, Cleaned.

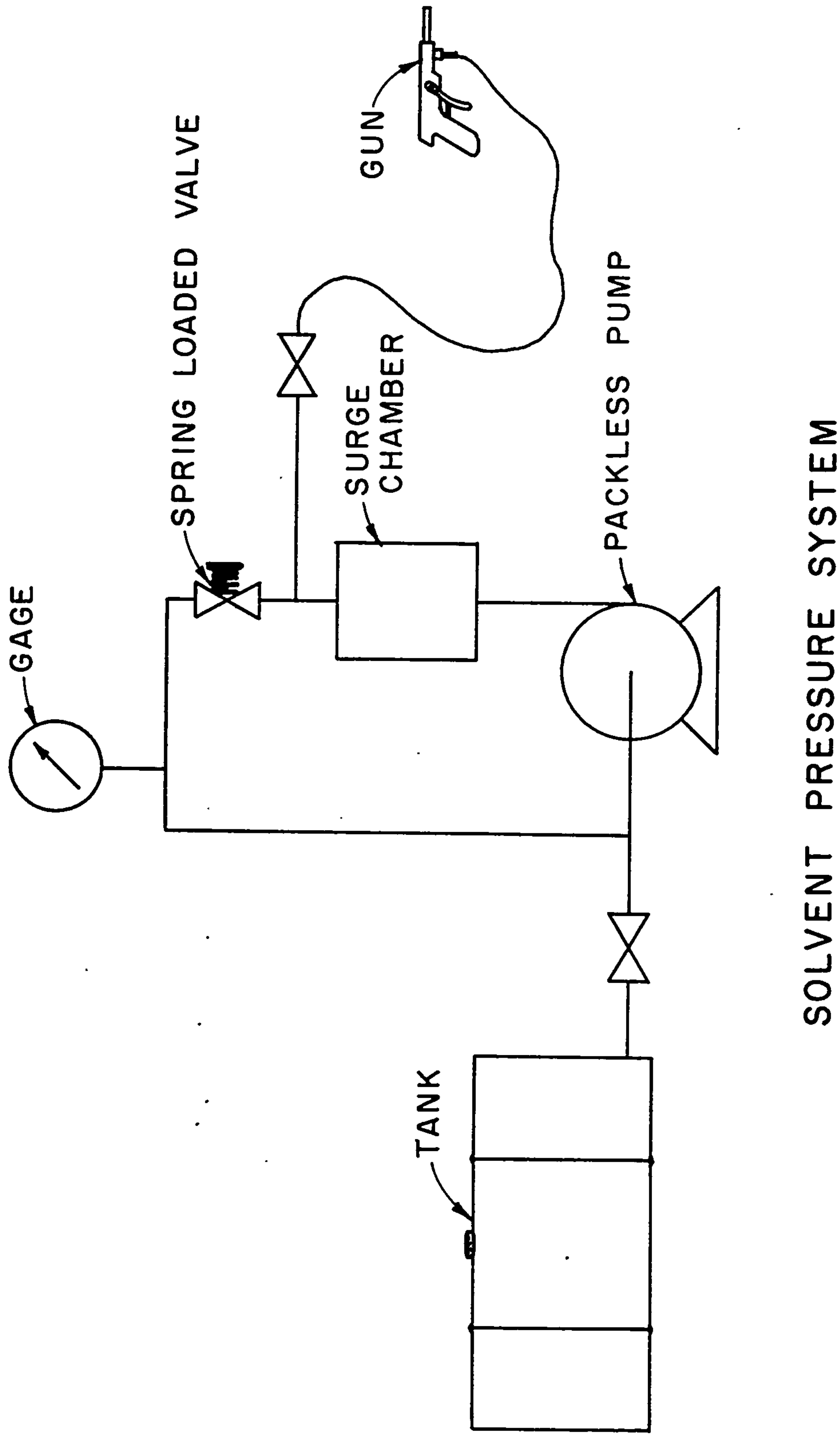


Figure 10. Schematic of Solvent System.

primed at all times and maintain the solvent in motion at a working pressure (Figure 11). Additional valves on the pump intake and exhaust lines allowed the tank to be refilled from solvent supply drums when gravity feed was not possible.

(Figure 11)

OPERATIONAL EXPERIENCES

The method for cleaning electric motors while in service, using carbon tetrachloride as the cleaning solvent, was used on several thousand motors ranging up to 150 horsepower. As many as 35 motors were cleaned by a crew of 5 men in a single day.

The simplified system--employing three men, using methyl chloroform (inhibited 1,1,1 trichloroethane) as the solvent, has been used to clean approximately 800 electric motors ranging up to 200 horsepower. Three motors reacted to the cleaning procedure but did not stop running. Shop examination of these motors indicated that a short circuit had existed in two of them for a very short period, but they did not catch fire. It was concluded that the solvent interrupted the short circuit and either prevented or extinguished any resulting fire. What occurred in the third motor was never definitely determined.

CONCLUSIONS

Safe handling of large amounts of hazardous cleaning solvents and the resultant vapors made possible the development of a method for cleaning electric motors while in service under normal load, without interrupting their operation, thereby extending their expected "use life".

The cleaning was done successfully with several different solvents. Motors as large as 200 horsepower were cleaned with the expenditure of approximately 2 manhours of labor and $7.35 for materials per motor.

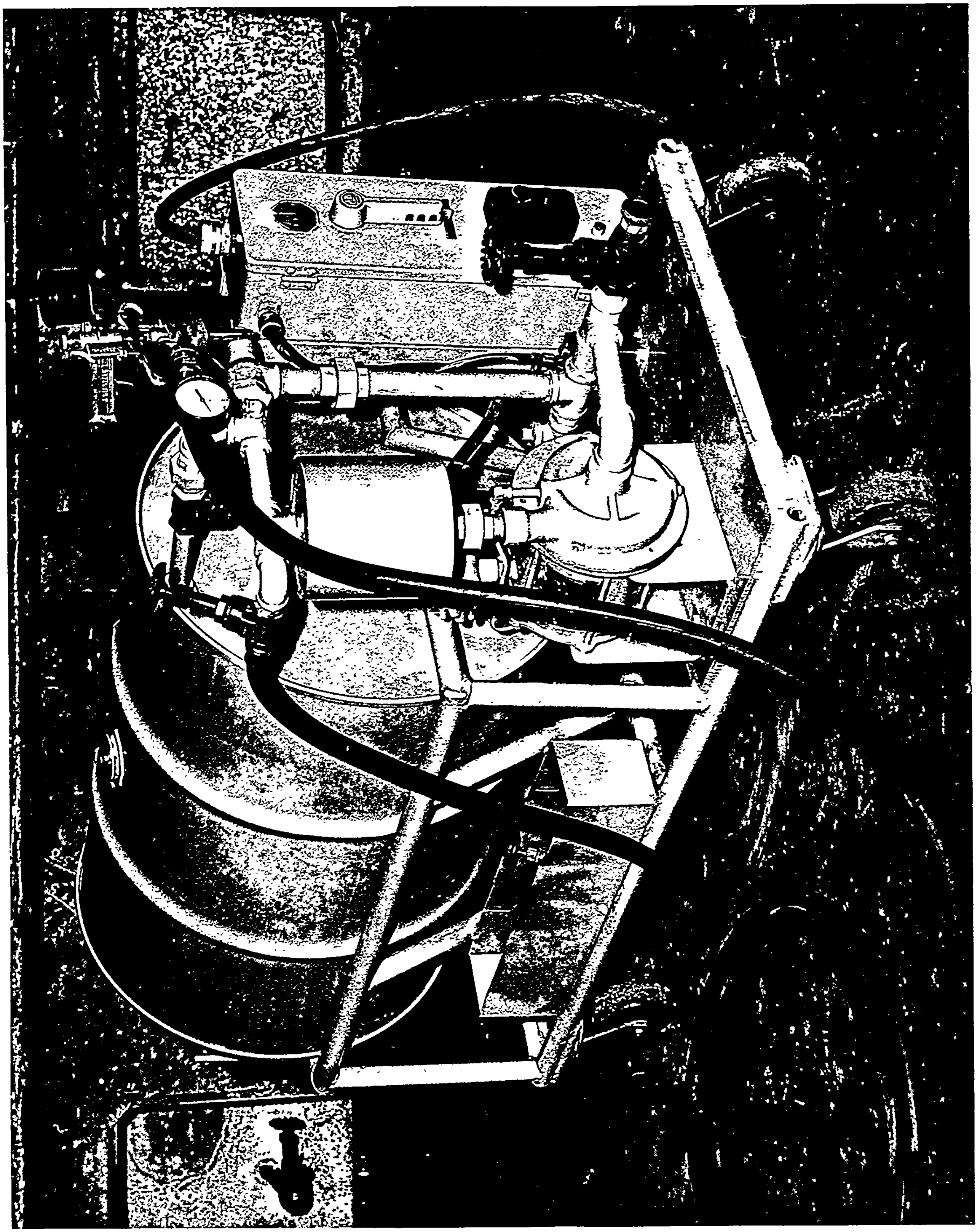


Figure 11. Solvent Cart.

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